CLAIMS

What is claimed is:

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1. An auto-calibrating spectrometer comprising:

a light source;

an optical element that transmits light and reflects a small amount of light;

a detector for outputting electrical signals corresponding to light signals that are detected thereby;

optical coupling apparatus that couples light from the light source to the optical element and a sample under measurement, and to the detector;

a shutter assembly that selectively couples light or inhibits light from impinging upon and reflected by a reference sample having known reflection or the sample under measurement; and

a controller coupled to the detector that processes the electrical signals output thereby and implements an algorithm that calculates a calibration value for the spectrometer at each wavelength of light output by the light source using a predetermined equation to autocalibrate the spectrometer.

2. The spectrometer recited in Claim 1 wherein the optical coupling apparatus comprises a fiber optic cable that couples light from the light source to the optical element, and which comprises at least one illumination fiber for coupling light to the sample under measurement, and a detector fiber that collects light reflected from the optical element and directs it to the detector.

3. The spectrometer recited in Claim 1 wherein the optical coupling apparatus comprises one or more lenses and a beam splitter that cooperate to couple light from the light source to the optical element and sample under measurement, and to the detector.

4. The spectrometer recited in Claim 1 wherein the light source comprises a polychromatic light source.

5. The spectrometer recited in Claim 1 wherein the light source comprises a monochromatic light source.

6. The spectrometer recited in Claim 1 further comprising a shutter assembly disposed between the light source and the fiber optic cable.

7. The spectrometer recited in Claim 1 wherein the optical element not anti-reflection coated.

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8. The spectrometer recited in Claim 1 wherein the fiber optic cable comprises a plurality of outer illumination fibers that surround a single detector fiber.

9. The spectrometer recited in Claim 4 further comprising a fixed grating disposed between the fiber optic cable and the detector that chromatically separates the light so that each pixel receives light of a distinct narrow range of wavelengths.

10. The spectrometer recited in Claim 1 wherein the predetermined equation is:

$$\text{Reflection} = I_i*((S_i-B2_i)-(B1_i-B3_i)/((R_i-B2_i)-(B1_i-B3_i)),$$

where, S_i is the signal strength at wavelength i for the sample under measurement, R_i is the signal strength at wavelength i for a reference sample of known reflection, $B1_i$ is the background signal strength at wavelength i with the light source on and with reflection only from the first focusing lens , $B2_i$ is the background signal strength at wavelength i with the light source off and the second shutter assembly open, $B3_i$ is the background signal strength at wavelength i with the light source off and the second shutter assembly closed, and I_i is the known reflection at wavelength i of the reference sample

11. The spectrometer recited in Claim 10 wherein the value R1 is computed using the equation:

$$Ri = Ri(0)*(B1_i-B3_i)/(B1_i(0)-B3_i(0))$$

where, $R_i(0)$ is the signal strength at wavelength i for the reference sample of known reflection at initial calibration, $B1_i$ is the current background signal strength at wavelength i with the light source off and the second shutter assembly closed, $B1_i$ (0) is the background signal strength at wavelength i with the light source on and the second shutter assembly closed at the time of initial calibration, $B3_i$ is the current background signal strength at wavelength i with the light source off and the second shutter assembly closed, and $B3_{i(0)}$ is the background signal strength at wavelength i with the light source off and the second shutter assembly closed at the time of initial calibration.

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12. The spectrometer recited in Claim 1 further comprising:

a second focusing lens 18 for receiving light that is transmitted by or reflected off of the sample under measurement toward it;

a second detector coupled to the controller; and

a second fiber optic cable for coupling light received by the second focusing lens to the second detector;

and wherein the controller processes the electrical signals output by the respective detectors and implements an algorithm that calculates a calibration value for the spectrometer at each wavelength of light output by the light source using a second predetermined equation to autocalibrate the spectrometer.

13. The spectrometer recited in Claim 12 wherein the second predetermined equation comprises:

$$\text{Transmission} = I_i*((S_i-B2_i)-(B1_i-B3_i)/((T_i-B2_i)-(B1_i-B3_i))$$

where, S_i is the signal strength at wavelength i for the unknown sample, T_i is the signal strength of the first detector at wavelength i for a reference sample of known transmission, $B1_i$ is the background signal strength of the first detector at wavelength i with the light source on and the second shutter assembly closed, $B2_i$ is the background signal strength of the first detector at wavelength i with the light source off and the second shutter assembly open, $B3_i$ is the background signal strength of the first detector at wavelength i with the light source off and the second shutter assembly closed, and I_i is the known transmission at wavelength i of the reference sample.

14. The spectrometer recited in Claim 13 wherein the value T1 is computed using the equation:

$$Ti = Ti(0)* (B1_{i2}-B3_{i2})/(B1_{i2}(0)-B3_{i2}(0))$$

where, $T_i(0)$ is the signal strength of the first detector at wavelength i for the reference sample at initial calibration, $B1_{i2}$ is the current background signal strength of the second detector at wavelength i with the light source is on and second shutter assembly is closed, $B1_{i2}0)$ is the background signal strength of the second detector at wavelength i with the light source on and the second shutter assembly closed at the time of initial calibration, $B3_{i2}$ is the current background signal strength of the second detector at wavelength i with the light source off and the second shutter assembly closed, and $B3_{i2(0)}$ is the background signal strength of the second detector with the light source off and the second shutter assembly closed at the time of initial calibration.

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15. An auto-calibrating method for use with a spectrometer comprising a light source, an optical element, a detector for outputting electrical signals corresponding to detected light signals, optical coupling apparatus that couples light from the light source to the optical element, and couples light reflected from the optical element and a sample under measurement to the detector, a shutter assembly that selectively couples light or inhibits light from impinging upon and reflected by a reference sample having known reflection or the sample under measurement, and a controller coupled to the detector that processes the electrical signals output thereby and implements the method to calculate a reflection value for the spectrometer at each wavelength of light output by the light source to autocalibrate the spectrometer, the method comprising the steps of:

performing an initial calibration of the spectrometer;

performing a background scan with the light source on and the second shutter assembly closed;

performing a background scan, if required, with the light source off and the second shutter assembly open;

performing a background scan with the light source off and the second shutter assembly closed; and

performing a sample scan of the sample under measurement with the light source on and second shutter assembly open.

16. The method recited in Claim 15 wherein the initial calibration step comprises the steps of:

performing a background scan with the light source on and the second shutter assembly closed;

performing a background scan with the light source off and the second shutter assembly open;

performing a background scan with the light source off and the second shutter assembly closed; and

performing a reference scan of a sample of known reflection with the light source on and the second shutter assembly open.

17. An auto-calibrating method for use with a spectrometer comprising a light source, an optical element, first and second detectors for outputting electrical signals corresponding to detected light signals, a shutter assembly that selectively couples light or inhibits light from impinging upon and reflected by a reference sample having known reflection or the sample under measurement, optical coupling apparatus for coupling

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light from the light source to the optical element, and coupling light reflected from the optical element and a sample under measurement to the first detector, and for coupling light that is transmitted by or reflected off of the sample under measurement to the second detector, and a controller coupled to the first and second detectors that processes the electrical signals output thereby and implements the method to calculate a transmission value for the spectrometer at each wavelength of light output by the light source to autocalibrate the spectrometer, the method comprising the steps of:

performing an initial calibration of the spectrometer;

performing a background scan of the first and second detectors with the light source on and the second shutter assembly closed;

performing a background scan, if required, of the first and second detectors with the light source off and the second shutter assembly open;

performing a background scan, if required, of the first and second detectors with the light source off and the second shutter assembly closed; and

performing a sample scan using the first detector of an unknown sample with the light source on and second shutter assembly open.

18. The method recited in Claim 17 wherein the initial calibration step comprises the steps of:

performing a background scan of the first and second detectors with the light source on and the second shutter assembly closed;

performing a background scan of both detectors with the light source off and the second shutter assembly open

performing a background scan of both detectors with the light source off and the second shutter assembly closed; and

performing a reference scan using the first detector of a sample of known transmission with that light source on and second shutter assembly open.